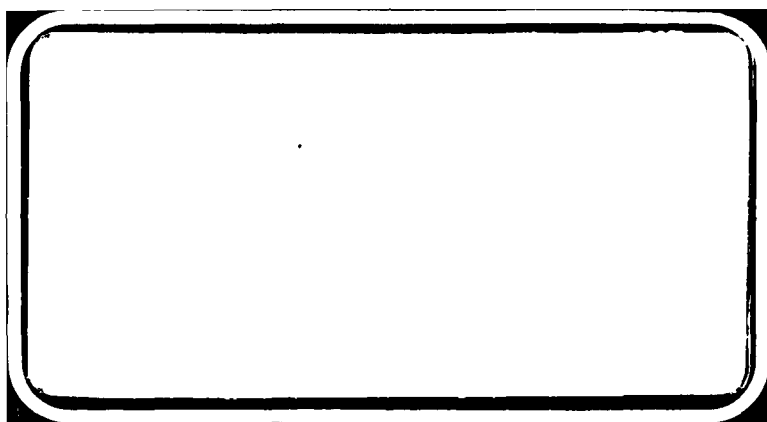


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FEBRUARY 1980

DCIEM Report No. 80-R-29

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A REVIEW OF THE  
ANTHROPOMETRIC AND STRENGTH STANDARDS  
OF THE  
CANADIAN MOTOR VEHICLE SAFETY STANDARD,

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# ABSTRACT

This paper reviews the anthropometric and strength criteria used by the CMVSS to specify vehicle design limits. The review was concerned with two main objectives:

- 1) To review the format and content of the CMVSS to ascertain whether the criteria contained therein are the most pertinent to vehicle safety characteristics and whether such criteria are presented in the most effective way possible;
- 2) To review available US and Canadian anthropometric literature to determine the extent to which existing data can be applied to standards for the design of vehicles for Canadian drivers and the cost/benefit of undertaking a comprehensive survey to provide more reliable data.

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## TABLE OF CONTENTS

ABSTRACT .....	111
PART I	
Information Required for a Standard and Method of Presentation...	2
PART II	
The Need for Additional Survey Data .....	9
DISCUSSION .....	13
CONCLUSIONS .....	15
RECOMMENDATIONS.....	16
REFERENCES .....	17
FIGURE 1 .....	20
FIGURE 2 .....	21
FIGURE 3.....	22
FIGURE 4.....	23
TABLE 2 .....	24
TABLE 3 .....	27

## INTRODUCTION

The Road Safety Unit (RSU), Ministry of Transport, published a review (Ref. 3) of the anthropometric and human force specifications contained in the Canada Motor Vehicle Safety Standard (CMVSS Ref. 7). The report concluded that:

- i) The CMVSS data on anthropometric dimensions and human force capabilities are neither complete nor completely accurate; and,
- ii) The US civilian data on which these data seem to be based do not necessarily describe the Canadian driving population.

The report concluded with the recommendation that a comprehensive survey of anthropometric and force capabilities of Canadian drivers be undertaken in order to obtain data needed to improve the accuracy and relevancy of the CMVSS.

DCIEM was asked to review the RSU report and comment on the desirability and/or feasibility of undertaking such a survey. The review was concerned with two main objectives:

- i) To review the format and content of the CMVSS to ascertain whether the criteria contained therein are the most pertinent to vehicle safety characteristics and whether such criteria are presented in the most effective way possible.
- ii) To review available US and Canadian anthropometric literature to determine the extent to which existing data can be applied to standards for the design of vehicles for Canadian drivers and the cost/benefit of undertaking a comprehensive survey to provide more reliable data.

This report is, therefore, organized in two parts: Part I deals with the nature of the information that should be included in the standard and the method of presentation of this information, and Part II considers the need to undertake a large-scale survey to obtain data on which such a standard should be based.

The scope of this report is limited to the consideration of the anthropometric and force criteria necessary to ensure safe performance of the driving task with some consideration given to the requirements of passenger restraint systems.

## Part 1

Information Required for a Standard and Method of Presentation

A review of the anthropometric information required for a Motor Vehicle Safety Standard is concerned with the two interrelated questions:

- i) What information should be included in a vehicle safety standard; and,
- ii) What is the most effective method by which such information can be presented, to ensure that the standard is accurately and reliably implemented.

At first it would appear logical to consider these questions in the order in which they appear above. Certainly, the most direct method of specifying standards is to present a comprehensive list of detailed design criteria. However, most human engineering specialists will agree that this 'cookbook' approach is far too tedious and too open to misinterpretation to be practical, owing to the rather large number of dimensions involved and the wide range of vehicle designs. Other approaches have therefore been considered, but of course, they determine to a large extent, the nature of the information which should be included in the standard. Therefore, the questions of format and content are somewhat interrelated and there shall be no attempt to separate them in the forthcoming discussion.

As noted above, it would be nearly impossible to identify every dimension which should be included in a standard which attempts to provide a comprehensive list of detailed design criteria; the dimensions involved are simply too numerous. Moreover, this approach would tend to discourage creativity and innovation on the part of designers, since such a cookbook standard may be difficult to implement in all cases.

The Current CMVSS

The standards contained in the CMVSS (Ref. 7) are a mixture of performance criteria, absolute design limits and design criteria based on anthropometric data as provided by the CMVSS. The CMVSS also provides sets of anthropometric data representing the 5th percentile adult female (5F), 50th percentile adult male (50M), 50th percentile 6-year old child (50C) and 95th percentile adult male (95M) because these sub-groups of the population are useful in defining the upper and lower design limits. Using conventional anthropometric data as the basis for design criteria requires that designers be competent in the use of such data and to be able to manipulate them to fit a

particular design. For example, the designer is required to be familiar with certain biomechanical properties of the human body to be able to determine the effect on overall dimensions of variations of the driver's posture. They also require the designer to compensate for the differences between static anthropometric measurements made in the laboratory and actual seated posture in a vehicle.

In other sections of the CMVSS, the finalized design is required to reach certain levels of performance in tests using 2D and 3D manikins representing the appropriate sub-group. That is, the vehicle design is required to reach a certain level of performance using measures specified in the particular test. Interestingly, many of the performance standards contained in the CMVSS are based on the Society of Automotive Engineers (SAE) procedures, standards and recommendations. In these cases CMVSS standards adopt the anthropometric and force data on which the respective SAE standards are based. Therefore the anthropometric data provided in the CMVSS are often superfluous to the actual standards. The RSU report presents a list of anthropometric dimensions implicit in the CMVSS. A closer examination of the CMVSS, summarized in Table 1, reveals that the only standards which in fact, make use of the anthropometric data contained in the CMVSS are those relating to the 'fit' of restraint belts. All of the other standards either refer to a SAE test procedure or provide absolute design values. Simply to upgrade the anthropometric data contained in the CMVSS, therefore, is not expected to have a significant impact on the relevancy of the CMVSS without a concomitant review and possible redefinition of all SAE manikins and specifications referenced in the CMVSS. The Society of Automotive Engineering of Japan, for example, has produced a modified SAE manikin which represents the range of drivers in that country, and it seems that both manikins are used in the development of vehicle interiors.

There are two conclusions which may be drawn from this situation. First, the conclusion reached by the RSU that the set of anthropometric variables implicit in the CMVSS is not complete, may not be entirely valid. Many more dimensions are implicit in the CMVSS, through reference to SAE standards, than are implied by Table 3 of the RSU report. The second point is that the actual anthropometric data contained in the CMVSS are much less critical than would normally be the case, because of the heavy reliance on other standards which are based on different data.



TABLE 1: SOURCE OF ANTHROPOMETRIC DATA IMPLICIT IN THE CMVSS

<u>Dimension from Table 3, RSU</u>	<u>STD.</u>	<u>DATA SOURCE</u>
1. Leg Force	105	SAE J937
2. Eye Height	107	SAE J941a
3. Functional Arm Reach	101	"within reach of driver"
4. Arc Swept by Head	200	measuring device 29" - 33"
5. Position of Back of Head	202	SAE J826 overall height set 27.5"
6. Arc Swept by Chest	203	SAE J944
7. Forward Extent of Abdomen	208	CMVSS 50C-95M
8. Chest Depth *	210	SAE J787b, SAE J826
9. Shoulder Height*	210	SAE J787b, SAE J826
10. Neck Width*	210	SAE J787b, SAE J826
11. Hip Breadth*	210	SAE J787b, SAE J826
12. Pelvic Width*	208	CMVSS 50C-95M
13. Body Weight	208	CMVSS 50C, 5F and 95M
14. Arm and Finger Force	209	no reference found
15. Fingertip Diameter	209	min. area .7 sq.in. min.dimension .4 in.

\* Dimension implicit in standards 208, 209 and 210 from general provision that "the seat must be capable of adjustment to fit occupants whose dimensions and weight range from those of the 5th percentile female to those of the 95th percentile male".

### Expansion of CMVSS

As noted above the set of anthropometric variables directly specified in the CMVSS was evaluated by the RSU and found to be incomplete. An expanded list of dimensions was developed and recommended by the RSU for inclusion in the CMVSS, based on the work of McFarland and Stoudt (Ref. 16) and Stoudt *et al.* (Ref. 23). Table 5 of the RSU report, reproduced here as Table 2 presents a list of anthropometric and force variables which the RSU recommends for inclusion in the standard together with the underlying rationale. In general, this recommended set of variables appears to be reasonably complete. However, a number of comments and qualifications are in order. The comments which follow refer to specific dimensions contained in Table 5 of the RSU report.

#### Specification No. 4 - Hip Sitting Breadth:

Specified as 95th percentile male, for the design of seat breadth and pelvic restraint. In fact, for this particular dimension, the female population may set the upper limit, and should be used as well as the male.

#### Specification No. 5 - Abdomen Depth:

Specified as 95th percentile male, for the design of backrest to steering wheel distance, and the design of pelvic restraint. The size range of pregnant drivers should also be considered.

#### Specification No. 9 - Elbow Rest Height:

Specified to establish the heights of elbow rests. The elbow rest height is actually a function of steering wheel height/rake/size, and distance from the Seat Reference Point - a very complicated measure highly dependent on the actual seating/steering geometry. This is an example of a case when it might be simpler to legislate for function ("arm rests shall not interfere with the driver's arms") rather than design ("arm rests shall be X inches above the seat reference point").

#### Specification No. 13 - Elbow to Elbow Breadth:

Specified as 95th percentile male, to establish lateral clearance. This dimension is highly dependent on clothing, because potentially six layers of clothing are involved. Canadian winter clothing should therefore be taken into account, but the point at which it affects safety is not clear.

Specification No. 16 - Eye Height:

Specified to identify the necessary height adjustment, and the eye-lipset for the field for the field of view. This is a good case where there is a low correlation between the 'classic' anthropometric measurement, and the actual position of the eye in the vehicle. The SAE eye-lipset is designed to provide information on the range of probable eye locations. However, seated eye height is affected by clothing, seat back angle, posture, etc., and is very hard to predict.

Specification No. 17 - Neck Width:

Specified for the design of upper torso restraint. This dimension is unlikely to be highly variable among adults, and it should be possible to establish reasonable design limits without surveying the driving population, particularly if a 'margin of error' is added. The use of the neck width to define the location of the torso restraint is also questionable, due to head/neck/body movements, and variations in sitting posture.

Specification No. 18 - Location of the Back of the Head:

Specified for the design of head restraints. This is another highly variable measure which is not normally included in anthropometric surveys, and given the additional effects of seating posture is of questionable value in designing head restraints.

Specification No. 19 - Fingertip diameters - Bare and Gloved Hand:

Specified to establish the hole diameter of button on buckle release. The rationale is questionable, if the way in which such buckles are released is studied. Users employ their thumb or finger, and tend to use the flat part of the palmar side of the finger, rather than the fingertip. The dimension of fingertip diameter itself is considered to be of little use in determining the operability of buckle releases, and, again, performance standards appear to be more appropriate than a physical design specification.

Specification No. 20 - Pelvic Width:

Specified to establish the location of the buckle of the pelvic restraint. The rationale given in Ref. 3 may be an over-simplification, but it is difficult to visualize a strong correlation

between the width of the pelvis and the location along the seat belt of the buckle. Location for ease of access/operation seems to be a more important requirement.

Specification No. 21 - Functional Leg Reach:

Specified to establish the "use of foot controls" and fore-aft seat adjustment. 'Functional leg reach' as such, is not normally measured (see Ref. 11 for example). What is probably required is the dynamic anthropometry approach used by Ely et al. (Ref. 10) to determine the overall pedal reach envelope.

Specification No. 22 - Functional Arm Reach:

Specified to establish the use of the manual controls, and rear view mirrors. "Functional arm reach" as routinely measured (see Ref. 11) provides only one static dimension which, therefore, identifies the user. If the vehicle design is to be legislated then the functional reach envelope is required, as determined for the driving population, for example in Ref. 12. However, the functional reach envelope is affected by seat geometry, clothing and restraint systems, requiring a very large study to acquire the necessary data. Again, therefore, it might be more effective to adopt a functional specification stating that all controls shall be easily operable by a driver having X inches functional reach, when wearing typical winter clothing.

Specification No. 23 - Arc Swept by Most Forward Position of Head As Occupant Leans Forward:

Specified to establish head impact areas. This arc is obviously a function of the restraining system and the deceleration level. It is not amenable to study by traditional anthropometric techniques, and unless such data are available from crash research it seems, again, that a functional approach should be taken for the specification, rather than a design approach.

Specification No. 24 - Arc Swept by Chest as Driver Leans Forward:

Specified to establish the location of the steering wheel and angle of the steering column. This recommendation runs counter to the conclusions which may be drawn from the work of Lehmann (Ref. 14) that the angle of the steering wheel is related to the maximum force, and the speed with which the wheel can be turned (hence the near horizontal wheel of the typical truck, and the near vertical wheel of the racing car). Lehmann also demonstrates that the steering wheel position has an important influence on driver comfort, and should be adjustable, at least along the steering column axis.

There are also some variables which are not recommended by RSU report which, it is considered, should be included. These are listed below:

Shoe length and breadth;

These dimensions were identified in Table 2 of Ref. 1 as being unusual measures, but considered necessary, since little is known about the operating foot. This argument is supported. Dimensions should be gathered on the length and width of the large winter footwear used in Canada.

Heel height;

Similarly to the above, dimensions of heel height, as affected by footwear should be gathered, because they influence the operability of foot controls. Cab designs should accommodate the full range of footwear (ie., sandals to muckluks) and allow for changing fashions.

#### Other Approaches to a Motor Vehicle Safety Standard

As noted earlier, the CMVSS adopts a large number of SAE performance standards and tests involving manikins. Although manikins provide a simple method for designing and evaluating workspace geometry, many manikins lack the flexibility required for wider ranging applications and, in addition, they often represent a specific sub-group of a specific population. The SAE H-point machine was designed to overcome many of the problems of other manikins. It is a 3D manikin with a mechanically hinged hip reference point and the thigh length and seated height can be adjusted to represent a wide range of "drivers". In addition, it is weighted to achieve realistic seat cushion depressions.

In itself, or as a follow-up to manikin tests, a subject pool could be used in the design of vehicle workspace. This would involve the selection of a cross-section of the user population according to the percentiles and variables of most interest. Selections would be based on existing percentile data which, admittedly, may not be totally accurate but accurate enough for this application. A 2.5 percentile female in height (and generally in the lower range on other key dimensions), and a 97.5 percentile male in height and selected other dimensions, along with a wide range of subjects in-between these extremes would give a fairly broad range of sizes which can be used in the final evaluation of the design prototype. Although, this is an "after the fact" type of approach, it has the advantage of obtaining direct, accurate feedback. This method takes human adaptability, comfort and flexibility into consideration; all of which are not accounted for in descriptive, numerical guides or mathematical models and manikins.

At the 'drawing board' stage, 2 dimensional manikins are available, as are computer models, both of which may be more suitable than

the physical manikins presently in use for the initial conceptualization of the design and subsequent development. One of the most widely published is BOEMAN (Ref. 19). Presently it is still experimental but it appears to have applications in the evaluation of crew station geometry. A model such as this may have application to automobile design. Another biomechanical model, COMBIMAN (Ref. 13) has universal application because the basic parameters of the model can be altered to represent any desired population whose anthropometric characteristics are known. A third model, the Computerized Accommodated Percentage Evaluation (CAPE) (Ref. 5) was specifically designed for cockpit applications. It determines the percentage of the potential user population that can be accommodated by a particular design. A similar model for vehicle applications could be used to ensure that a minimum percentage of the drivers are accommodated.

The present state-of-the-art for computer models, COMBIMAN, CAPE and BOEMAN does not appear to be sufficiently advanced at this time to replace the physical models. They have the potential, however, of becoming the most relevant and effective method for ensuring minimum safety standards in vehicle design because they can combine anthropometric variables with biomechanical models to provide an overall human analogue which can be easily and reliably implemented at all stages of the design process.

## Part II

### The Need for Additional Survey Data

This part considers the need, as identified by the RSU, to undertake a large-scale survey of Canadian drivers in order to update the anthropometric and force data contained in the CMVSS. Many aspects of this question were considered. For example, do these data already exist, can American population data be used, how much improvement can be expected from a large-scale survey, can such a survey be undertaken reliably, what other problems are there, what is the cost of such a survey, do the benefits outweigh the costs?

A literature survey was conducted in order to determine what information is available, and how reliable that information is.

Many anthropometric surveys are reported in the literature (see for example, "A Collation of Anthropometry, Ref. 11). The majority however, are either too small to be significant or are restricted to specific population sub-groups, such as military aircrew or air traffic controllers, which have little relevance to private or commercial vehicle design. The major surveys of importance will be discussed in light of their application to these problems. It should be noted that no relevant data have been found which reliably describe the force characteristics of the driver population.

a) Data Describing the Canadian Population:

- i) Bureau of Nutritional Sciences Department of National Health and Welfare (Ref.6)- The most recent large scale survey was carried out in 1970. It was a profile of 14 measurements on 11,615 subjects representing the Canadian population aged 0-65 years. At this time, only data on height and weight are available.
- ii) Pett et al. Canadian Bulletin on Nutrition (Ref. 17)-The first nation-wide survey of heights and weights in Canada was conducted in 1953. This survey was a statistically designed probability sample intended to give population estimates. The sample included 22,000 males and females.

b) Data Describing the U.S. Population:

- i) Stoudt et al., U.S. Department of Health Education and Welfare (Ref. 22)-The survey was conducted during 1960 - 1962 on a probability sample representing the general population of the United States (ie., civilian, non-institutional, adult population). Over 6600 subjects between the ages of 18 to 79 were measured.
- ii) Stoudt et al., U.S. Department of Transport (Ref. 23)-Static and dynamic factors in determining driver workspace were examined on a sample thought to represent the American driver in 1970. Over 1,000 subjects ranging from 16 to 68 years of age provided data on 21 static dimensions pertinent to vehicle design. It was concluded that the driving population is anthropometrically different from the general population.
- iii) Abraham, U.S. Department of Health, Education and Welfare (Ref. 2)-This is a U.S. Health and Nutrition Examination (HANES) carried out in 1971 - 1972. The data were collected on a probability sample of the U.S. population by age,

sex, race, and income level. The pertinent data are limited to height and weight. The Hanes Survey showed that income level and nutritional status were important factors in determining variability of body dimensions.

- iv) Sahley, Cleveland Designers and Consultants (Ref. 20) - This survey by Sahley is worthwhile mentioning because it provides dimensions of the human figure for 6283 male and female, American civilians. Unfortunately, the report was not available at the time of writing.

Cross comparisons of data from these surveys were made in an effort to establish the similarities and differences, and to provide a better understanding of their reliability.

A comparison of Stoudt's 1970 survey of American drivers, and Stoudt's survey of the U.S. civilian population in 1962 showed that male drivers in 1970 were on the average 12 lbs. heavier and 1.6 inches taller than the average male surveyed in 1960 - 62. Differences between the female populations were less marked. Unfortunately, 16 and 17 year-olds were not included in the sample of the U.S. civilian population measured which may account for some of the differences found.

A comparison between anthropometric data from Stoudt's 1962 survey of U.S. civilians and the CMVSS criteria indicates a strong likelihood that the CMVSS standard is based on the 1962 survey. If this were true, the standard may not take into account the younger drivers (the 16 and 17 year-olds) and this group may have a significant influence on anthropometric size distributions of drivers. For example, it is known (Ref.20) that females do not usually reach full growth by age 17. A distribution of drivers by age (Ref.3) in five Canadian provinces shows that drivers in the 16 - 19 year-old category make up about 8% of the total driver population. Thus a population sample which ignores the 16 and 17 year-old driver group could be biased in favour of the larger driver.

A comparison was made of the two major civilian surveys of Canadian and American populations, the U.S. 1960 - 1962 survey (Ref.22) and Canadian 1970 - 71 survey (Ref.6). Although the Canadian data are very limited, the two dimensions of height and weight were used because they correlate with other body dimensions. The height and weight comparisons are shown in Figures. 1 - 4. Unfortunately, no direct statistical comparison can be made between the two sets of data without making unjustified assumptions or manipulations. However,



qualitative comparisons indicate that U.S. males are somewhat heavier and taller than Canadian males (Figs. 1,2) and U.S. females are somewhat heavier than Canadian females (Fig.4) but of similar stature (Fig.3). Since height and weight correlate well with other body dimensions and the Americans seem to fall into roughly the same range as Canadians, it would seem reasonable to expect that the two groups would also be similar on other body dimensions. From this comparison, it would appear that design criteria based on American data can also be reliably used to accommodate Canadian drivers.

Table 3 presents a comparison (based on the work of Bartz and Giancotti (Ref. 4) of five anthropometric variables from five different population surveys. Although statistically speaking, the differences between data appear to be somewhat high in some dimensions, ie., 9.7% variation in seat breadth, from a practical point of view, the data are remarkably similar, considering the differences in the age and population makeup of the surveys. In absolute terms, the largest variation was  $1\frac{1}{2}$  inches found in height and sitting height. This variation is relatively small when compared to the design tolerances which are necessary to accommodate a wide range of postures and to permit adequate ingress and egress. Moreover, from a safety point of view, it would be reasonable to use the more conservative value for specifying eye heights and related seat dimensions since this lower limit encompasses the other data. Hence, for example, the 5th percentile female sitting height would be taken as 30.98 inches for specifying lower limit criteria. Other anthropometric dimensions, such as fingertip dimensions show such little variation that the overall range could be estimated reasonably accurately without the need for an extensive survey.

To a certain extent therefore, data are available which can be used to update the CMVSS. However, some data may not be sufficiently accurate and others, such as force data, are non-existent. Nevertheless, before embarking on a large-scale survey, some evaluation of the expected gains should be made as well as consideration given to the problems which will have to be faced. Firstly, anthropometric dimensions measured using conventional techniques, and standardized erect postures are difficult to apply directly to the design of vehicles because the sitting geometry is completely altered. For example, it is difficult to determine seat height, based on popliteal height unless the designer knows how changes in legs, knee and ankle angles effect the overall measurement. Secondly, consideration must be given to the effect of clothing. The wide range of clothing worn by Canadian drivers introduces a degree of uncertainty about the measurements taken. Clothing not only affects overall size, by as much as 3 inches in some cases, but also may affect the ability of the driver to reach and operate certain equipment.

## DISCUSSION

Well human engineered vehicles are designed to accommodate a wide range of driver sizes, the usual design limits should be set by the 5%ile and 95%ile drivers. To date, the two most important studies of driver anthropometry are Stoudt's 1960 - 1962 National Health Survey and the 1970 Stoudt Survey for the U.S. Dept. of Transport (Ref. 23). Assuming these studies can be used to approximate the Canadian driver, to the accuracy required, the combined data present 16 of the 21 static dimensions deemed necessary by RSU for inclusion in the CMVSS. The five measurements recommended by RSU and missing from these studies are not considered to justify a survey for the following reasons:

1. Chest depth - can be estimated from abdomen depth for purposes of design of upper torso restraint;
2. Shoulder breadth - can be estimated from elbow breadth for designing backrest;
3. Neck width - has a negligible effect on design of upper torso restraint when compared to range in location of the head and posture;
4. Fingertip diameter - range of size insignificant;
5. Pelvic width - can be estimated from hip sitting breadth for purposes of locating restraint components.

The expected gains from an extensive anthropometric survey of Canadian drivers must be weighted against the costs, both financial and otherwise. There are a number of limitations inherent in anthropometric surveys of any kind. The reliability of the data depends upon sampling strategies and technique. These can be overcome to some extent but not eliminated.

A large-scale survey must include members of different racial subgroups, people from urban and rural communities, of different age groups, of different socio-economic backgrounds, etc. Similarly, the question of whether or not to pay subjects could be a significant factor affecting data reliability. For example, overweight people would probably be loath to volunteer to be measured. On the other hand, paying subjects to be measured may attract certain segments of the population and bias the overall results. In this area, DCIEM must defer to the expertise of the market research specialists who routinely deal with such matters. Whatever the sampling and administration strategy, the data obtained will provide estimates for population characteristics whose validity would be very difficult to determine due to the complexity and inter-relationships of the many factors involved.

Some information about vehicle design, manufacture and quality control would also be necessary in order to evaluate the benefits gained by a large-scale anthropometric survey. For example, what is the cost implication of designing for the range of sitting height 30.4" to 38.0" versus the range of 32.4" to 38.0"? Similarly, what are the manufacturing tolerances, for example, on the height of the driver's seat?

More information on driver behaviour and adaptability would also be required. Do drivers adjust their seats, restraint devices, controls, etc., to the optimal configuration, or do they adapt to a poorly adjusted seat? To what extent will drivers adapt to fixed designs before safety is compromised? This information would be helpful to determine the precision of the measurements sought, from a practical point of view, and the real necessity of a large-scale anthropometric survey.

Finally, these questions must be considered within the context of the move towards international standards on vehicle design which is gaining momentum both within the International Standards Organization, and within companies whose policy is now to market a 'world car'.

Unfortunately, there are no good data on the dynamic anthropometric measurements which are recommended by the RSU and which the authors agree are important. These include functional control envelopes and strength measurements. These measurements are the most difficult to specify, measure, interpret and incorporate in design standards. For example, what strength measurements should be taken and how can they be translated into design limits of steering wheel torque for prolonged driving? Similarly, controls may be located within the driver's operational envelope, yet considered too far to operate safely. It may be more appropriate to approach this area from the point of view of performance standards rather than design standards. This approach does not negate the need to obtain measures needed to establish safe operating envelopes and strength limits, but it may help to establish which measures are needed and how the current standards can be changed.

To be sure, there are some advantages to carrying out a survey of Canadian drivers. Notwithstanding the problems inherent in this type of survey it may provide more accurate and complete data on Canadian drivers than currently available. With more accurate data a designer would be able to better predict the number of people who are discommoded due to a particular design. Tradeoffs could be more accurately integrated. But, can such a survey be justified when all factors are considered? It must be questioned just how much knowledge would be gained above and beyond what is already known about the anthropometry of drivers. Since data on American drivers and civilians do exist, and it has been shown that Canadians are similar in some respects

(height and weight), there is not likely a great enough demand to warrant a large-scale survey, given all the limitations and considerations discussed. In other words it may be possible to upgrade the CMVSS sufficiently without gathering new data. It might also be mentioned at this point that it is the upper and lower limits of size that are the critical ones and if they cannot be met, then an attempt is simply made to come as close as possible to them in the design stage.

There are other approaches which can be taken to update the data specified by CMVSS than the large-scale survey proposed by RSU. It is possible to conduct a small-scale survey to collect data on the size extremes of the driving population, ie., 5th and 95th percentiles to establish bivariate distributions of the critical dimensions. Fifth to 95th percentile ranges for height and weight can be estimated reasonably accurately from available data. This approach provides useful information about the population extremes which are of prime importance for establishing design limits. The disadvantage is that accurate percentile distributions for the measurements taken cannot be established.

Using a 'margin of safety' approach may also eliminate the need for precise and accurate data. Using existing data from a number of sources, it may be possible to establish 'safe' limits by using the most conservative measures.

Synthesizing a population is another option which should be seriously considered. Population synthesis is a method used when the anthropometric data describing a user population are not available. This involves the processing of information available in other surveys to describe the 'new' population. Unknown dimension distributions can also be estimated.

#### CONCLUSION:

The conclusion reached by RSU, that the design criteria included in CMVSS do not cater to Canadian drivers, appears to be well founded inasmuch as they are based on a U.S. user population. However, before embarking on a major survey, there are several issues which should be addressed. For example, who should be measured, what age groups, what ethnic background, in what regions, whether subjects should be paid, how should subjects be obtained, what they should wear, which measures should be taken and how and what postures subjects should use - these are examples of issues which may not be easily resolved without further study or without the assistance of outside consultants. Further insight into driver behaviour and adaptability are required to better define the type of criteria which should be included in the CMVSS. The danger of embarking on a major survey prematurely is in obtaining accurate population descriptions which are irrelevant or inappropriate to the design of the driver's workstation.

It should be noted that for design purposes the driving population should be defined as consisting of people who are old enough to drive and who are free of physical or mental defects which may affect their ability to drive. That is, vehicle design should cater to the general public, not merely to people who drive now. Moreover, criteria need not be based on small females and large males. Since both sexes are involved, design limits should be based on the appropriate cut-off criteria of the distribution of the combined data.

For the time being, the range in size of Canadian drivers can be generated reasonably accurately from available Canadian and U.S. anthropometric data. By using conservative estimates, criteria can be established which ensure that at least 98% of the general population would be accommodated by resultant designs. Although criteria derived in this way do not have the same degree of authority as criteria based on data specifically collected for this purpose, they would certainly be more accurate than criteria currently specified in CMVSS.

Some of the variables which are pertinent to vehicle design, particularly the dynamic variables such as operating envelopes and strength capabilities, cannot be estimated for the driver population because the majority of available data of this type are specific to other user groups. However, from the legislative point of view, it may be more efficacious to establish performance standards for these areas as opposed to detailed design standards. An example of such a standard may be that 'all hand and foot controls must be within reach of the 2½ percentile driver (arm or leg length) while wearing winter clothing'.

#### RECOMMENDATIONS

It is not considered that a comprehensive anthropometric and strength survey of Canadian drivers is warranted at this time.

It is recommended that the anthropometric data contained in the CMVSS be upgraded using conservative estimates from available U.S. and Canadian data.

It is recommended that studies be undertaken to determine driver sitting behaviour, including, postural variations, seat adjustment and driver adaptability.

It is recommended that the automobile production process, from the initial design conceptualization through to manufacture, be reviewed in order to obtain a better insight into the critical factors of design and the tradeoff implications of altering design tolerances and quality control tolerances.

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FIGURE 1

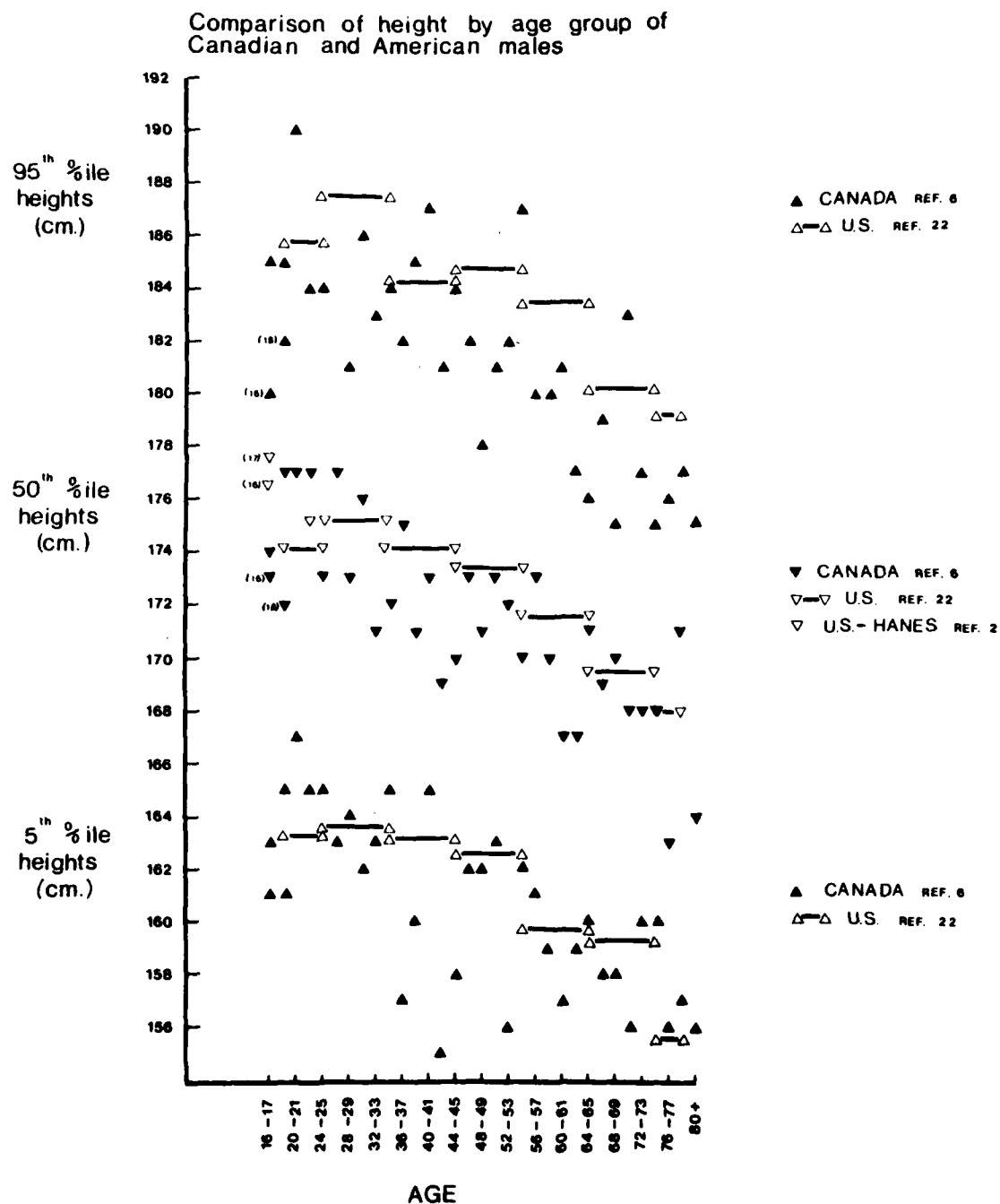


FIGURE 2

Comparison of weight by age group  
of Canadian and American males

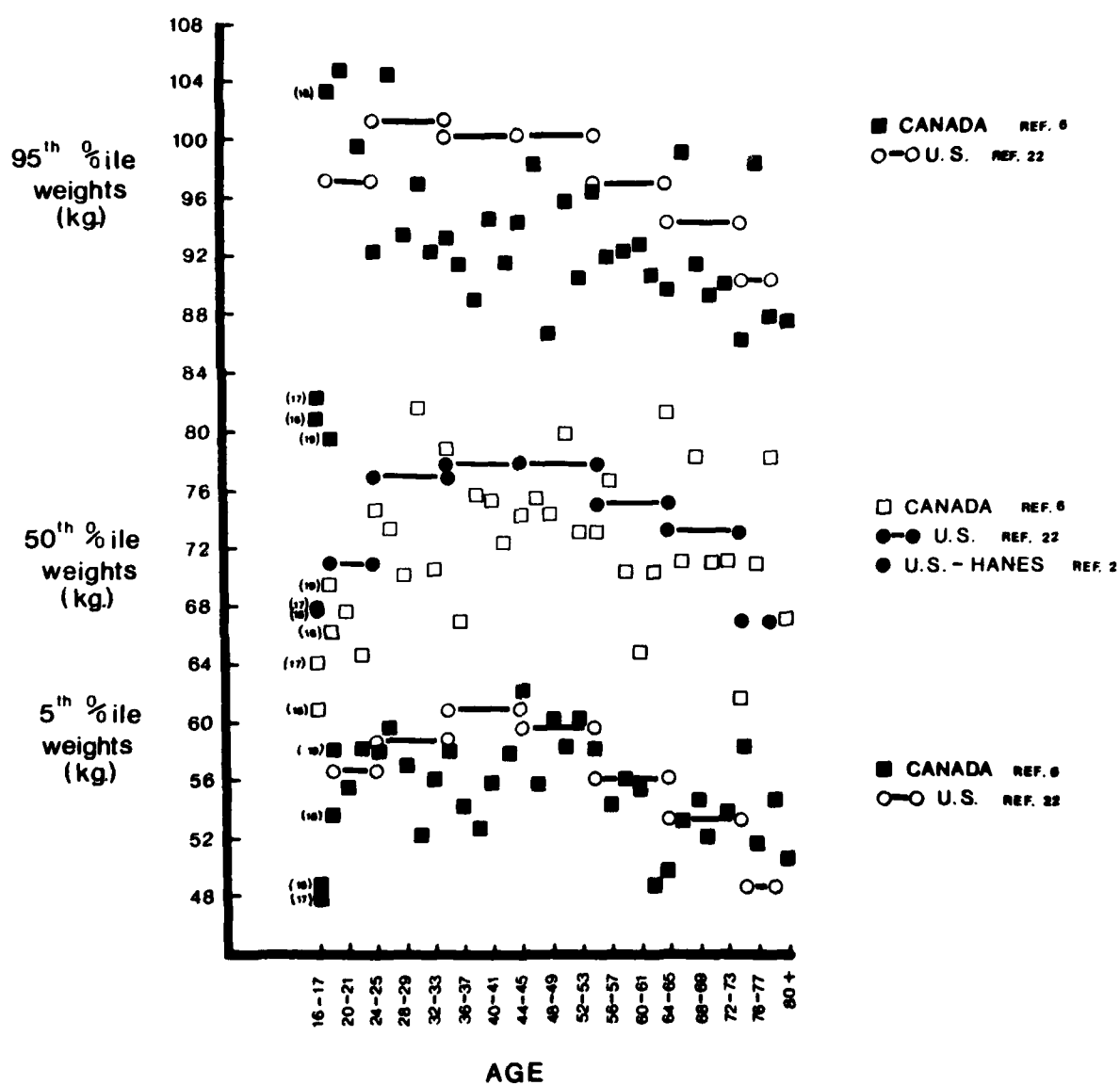


FIGURE 3

Comparison of height by age group  
of Canadian and American females

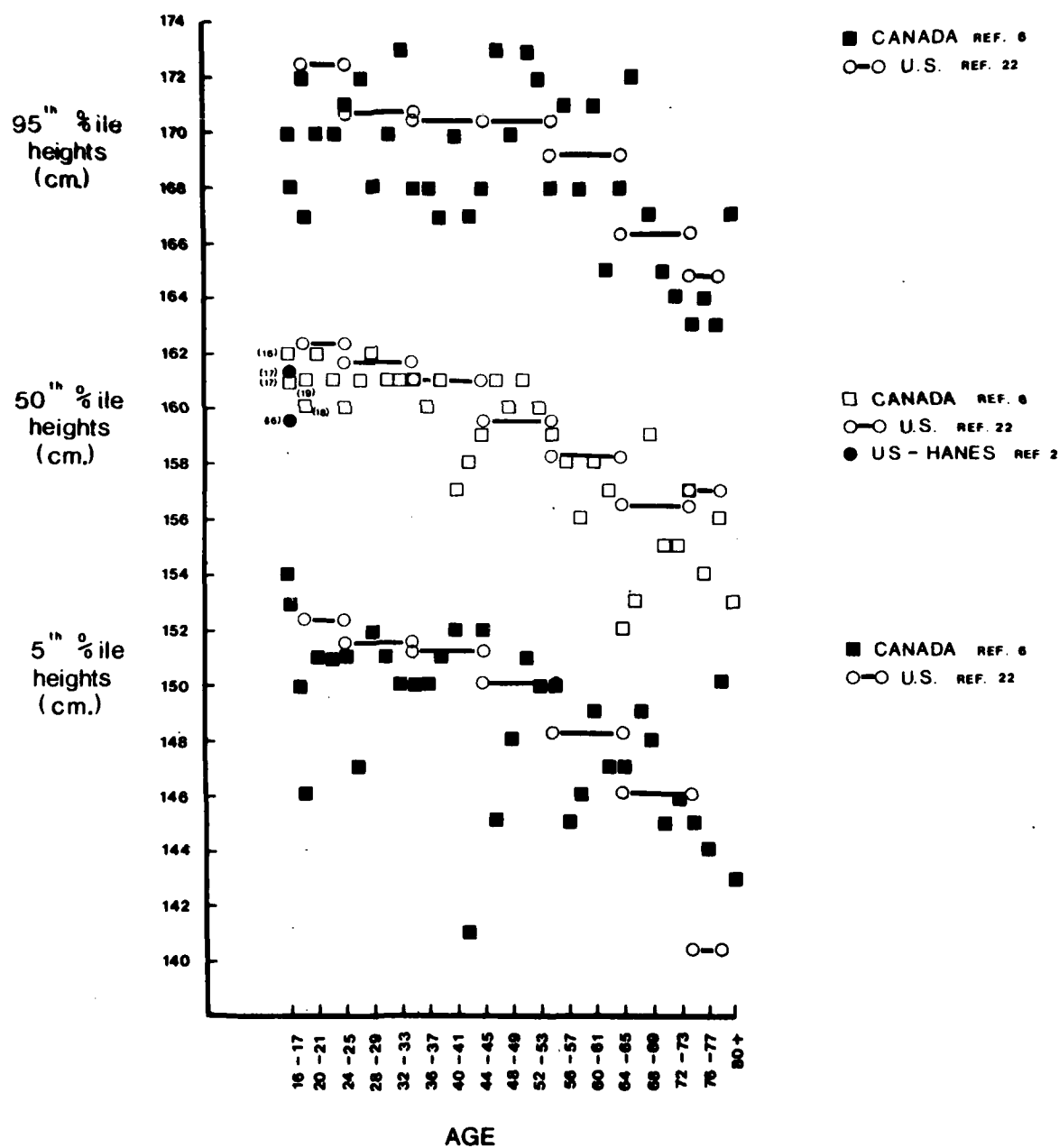


FIGURE 4

Comparison of weight by age group of  
Canadian and American females

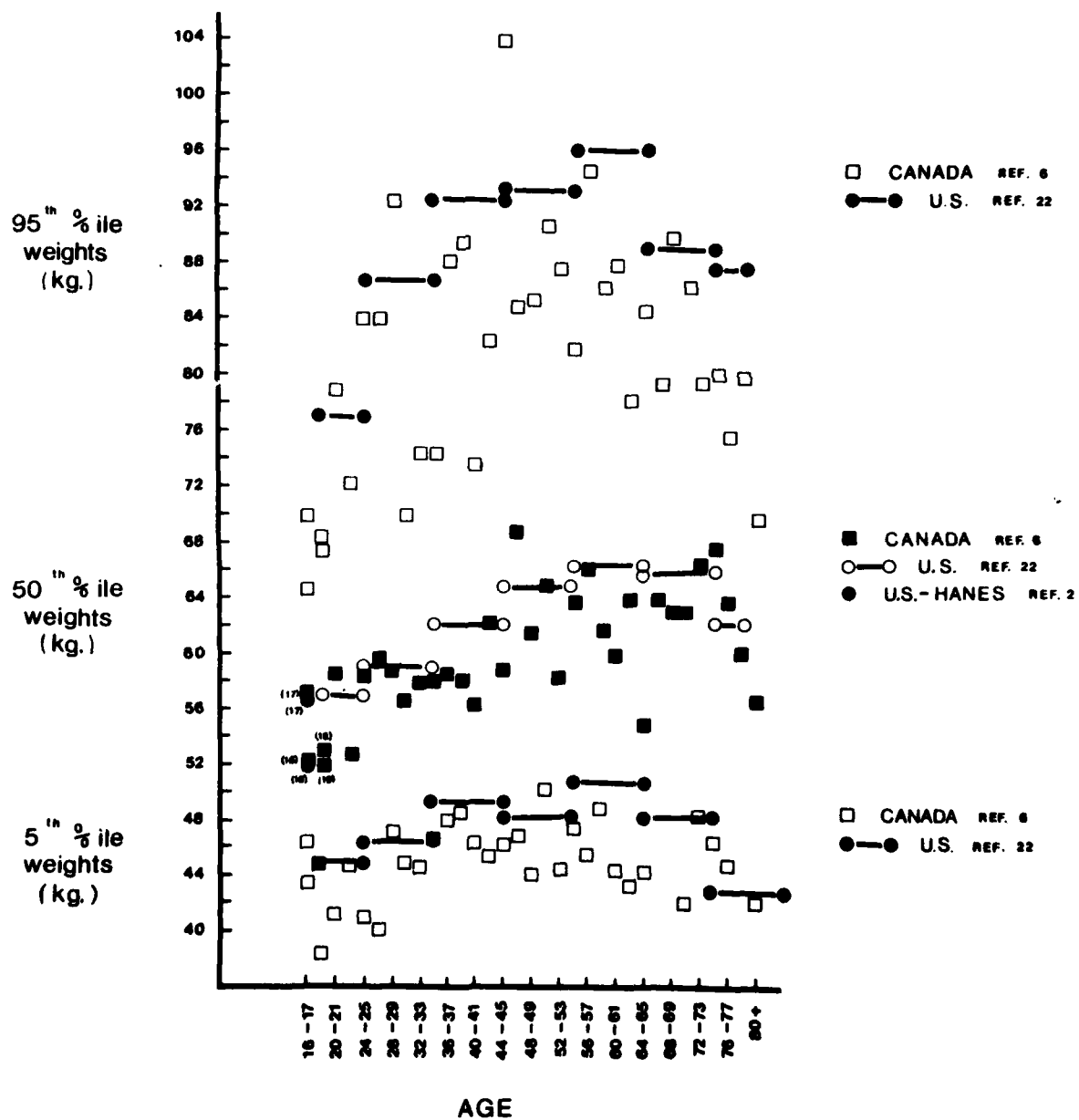


Table 2

Anthropometric and force specifications recommended for inclusion in  
the Canada Motor Vehicle Safety Standards<sup>1</sup>

Specification	Population of Particular Interest <sup>2</sup>	Recommended Technique <sup>3</sup>	Rationale
Static anthropometric measurements:			
1. Weight	C, 5F, 95M	A	<ul style="list-style-type: none"> <li>- correlation with body girths</li> <li>- establish minimum weights to activate restraint warning system</li> </ul>
2. Height	C, 5F, 95M	A	<ul style="list-style-type: none"> <li>- correlation with lengths of body members</li> </ul>
3. Erect sitting height	95M	A	<ul style="list-style-type: none"> <li>- seat to roof distance</li> <li>- pelvic restraint</li> </ul>
4. Hip sitting breadth	C, 95M	A or B	<ul style="list-style-type: none"> <li>- seat breadth</li> </ul>
5. Abdomen depth	C, 95M	B	<ul style="list-style-type: none"> <li>- backrest to steering wheel distance</li> <li>- design of pelvic restraint</li> </ul>
6. Chest depth	C, 95M	A or B	<ul style="list-style-type: none"> <li>- design of upper torso restraints</li> </ul>
7. Knee height	95M	A	<ul style="list-style-type: none"> <li>- pedal to steering wheel distance</li> <li>- floor to dashboard clearance</li> </ul>
8. Popliteal height	5F, 95M	A	<ul style="list-style-type: none"> <li>- seat height</li> </ul>
9. Elbow rest height	5F, 95M	A	<ul style="list-style-type: none"> <li>- establishing heights of elbow rests</li> </ul>
10. Thigh clearance height	95M	A	<ul style="list-style-type: none"> <li>- seat to steering wheel distance</li> </ul>
11. Buttock-knee length	95M	A	<ul style="list-style-type: none"> <li>- backrest to dashboard distance</li> </ul>

-2-  
Table 2

12. Buttock-popliteal length	5F	A	- seat lengths
13. Elbow to elbow breadth	95M	A or B	- establishing lateral clearances
14. Shoulder height	C, 95M	B	- backrest height upper torso restraint
15. Shoulder breadth	95M	A or B	- backrest width
16. Eye height	5F, 95M	B	- vertical seat adjustment
17. Neck width	C, 95M	A	- upper torso restraint
18. Location of back of head	95M	B	- head restraints
19. Fingertip diameters (bare and gloved hand)	95M	A	- hole diameter of button on buckle release
20. Pelvic width	95M	A or B	- establish location of buckle on pelvic restraint
Dyanamic anthropometric measurements:			
21. Functional leg reach	5F	B	- use of foot controls fore-aft seat adjustment
22. Functional arm reach	5F	B	- use of manual controls, and rear view mirror
23. Arc swept by most forward portion of head as occupant leans forward	95M	B	- head impact areas

TABLE 3

Comparison of Anthropometric Data Obtained by Several Investigators\*

Ss	Dimension	Stoudt 1960 - 62 U.S. (mean)	Sahley U.S. civilian 1957	Damon et al ( ref 7 )	Clauser	Stoudt (drivers) (1970)	max	%
5th Percentile Female	Height (inch)	59.0	60.5	59.9	60.0	58.9	1.5	2.5
	Sitting Height (erect)	30.9	32.0	32.4	31.7	--	1.5	4.8
	Seat Breadth (sitting)	12.3	13.3	13.5	13.3	--	1.2	9.7
	Knee Height Weight	17.9 47.3	--	17.2	--	-- 45.4	0.7 1.9	4.1 4.2
50th Percentile Female	Height (inch)	62.9	64.2	63.9	63.8	63.5	1.3	2.1
	Sitting Height	33.4	33.6	34.1	33.7	--	0.7	2.1
	Seat Breadth	14.3	15.0	15.0	15.0	--	0.7	4.7
	Knee Height Weight	19.6 62.3	--	18.8	--	-- 58.2	0.8 4.1	4.3 7.0
50th Percentile Male	Height (inch)	68.3	69.0	69.1	--	69.8	1.5	2.2
	Sitting Height	35.7	36.2	36.0	--	--	0.5	1.4
	Seat Breadth	14.0	14.0	13.9	--	--	0.1	0.7
	Knee Height Weight	21.4 75.5	21.7	21.7	--	-- 79.5	0.3 4.0	1.4 5.3
95th Percentile Male	Height (inch)	72.8	73.2	73.1	--	74.3	1.5	2.1
	Sitting Height	38.0	37.9	38.0	--	--	0.1	0.3
	Seat Breadth	15.9	15.5	15.4	--	--	0.5	3.2
	Knee Height Weight	23.4 98.6	23.0	23.3	--	-- 103.8	0.4 5.2	1.7 5.3

\* Expansion of table from Bartz and Giancotti (Ref. 4) page 2

-3-  
Table 2

24. Arc swept by chest as driver leans forward	5F, 95M	B	- location of steering wheel and angle of steering column
25. Leg force	5F	C	- specify minimum effective brake pedal pressures
26. Arm strength (rotational)	5F	C	- establish minimum effort required to steer automobile
27. Arm and finger force (specific applica- tion)	C	A	- establish minimum effort required to use restraints

1 Consistent with the current Canadian effort to change over to the metric system, all measurements should be listed in both fps and cgs notation.

2 Legend: C = child

5F = 5th percentile adult female

95M = 95th percentile adult male

3 A = Stoudt et al. 1965 (Ref. 22)

B = Stoudt et al. 1970 (Ref. 23)

C = Pierce et al. 1973 (Ref. 18)